URI RAMboat 2011 Design - AUVSI ASV Competition

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Abstract *– URI's student ASV (RAMboat2011- Figure 1), based on a Hobie Float Cat 60, is a stable platform first designed in 2010 and has been much improved upon for the 2011 ASV competition. A watertight electronics box is mounted forward of the payload space, with a camera, GPS, and water cannon mounted on the forward scaffolding. An extendable arm is mounted forward along the side for tennis ball retrieval. RAMboat electronics were adapted from URI's student AUV, with a separate higher power circuit newly designed for the ASV motor power. The motor power this year is provided with 4 Lithium-Poly batteries in parallel to save weight from the Lead Acid battery used in 2010. The electronics subsystems include a FitPC running C++ code on a Ubuntu Linux OS for image processing, laser ranging and thermal sensing, a custom Netburner 5282 embedded microcontroller mission computer, a one watt wireless hub for communication and programming, and two custom power management boards. The power board combines two system batteries and produces supply voltages, monitors consumption, optically isolates computers, and allows radio control takeover of motors. A second board was designed and built to combine the 4 new Lithium-Poly batteries used for motor power. RAMboat power consists of four 14.8 volt 10Ahr batteries for motor power and two 14.8V 6.4Ahr system batteries. A dual channel motor controller sits beside the power board to provide power to the dual Sevylor, 18lb thrust trolling motors. The mission computer runs a linked list table of mission legs which include speed, heading, GPS waypoints, and actions requests. Besides water cannon fire and tennis ball grabbing, the primary leg based requests are for vision guidance from the Fit PC, including camera pan/tilt angles. The vision analysis preformed on FitPC can be used to provide leg modifiers which control vessel guidance as well as tennis ball retrieval, thermal sensing, and cannon fire.*

Figure 1 RAMboat 2011

1 Introduction

RAMboat2011-ASV is the 3rd entry from the University of Rhode Island (URI) in the AUVSI International ASV competition, though URI has been a participant in AUVSI AUV student competitions for over a decade. Electronics developed for URI's 2009 AUV and the 2010 RAMboat platform have been adapted to be URI's 2011 ASV, in order to accomplish the missions planned for the competition in Norfolk, VA (Figure 2). With limited funds and the need for both AUV and ASV electronics, the design approach has been that the ASV use compatible AUV hardware as much as possible. This includes a custom 5282 embedded microcontroller mission computer with compass, A2D sensing capability, UDP communication and servo control implemented, wireless hub for communications and programming, and new FitPC vision computer along with a USB camera, thermal sensor and laser ranging system. Additionally a modified RV water pump was employed as a water cannon and a solenoid for tennis ball retrieval was implemented.

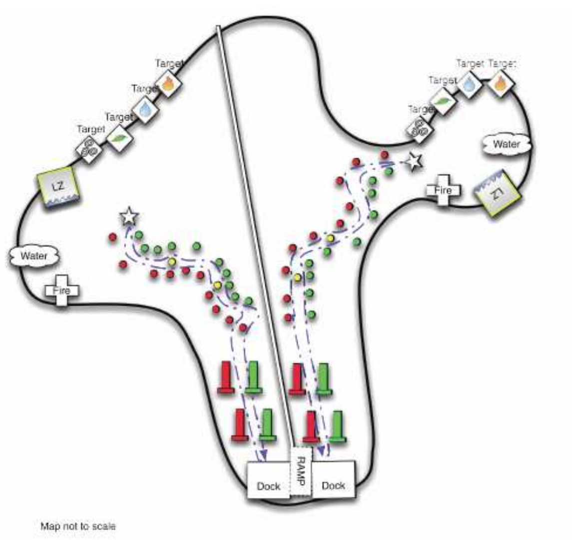


Figure 2 AUVSI Mission for 2011

Work on URI RAMboat ASV development began in 2010 with a team of students developing an ASV to operate semi-autonomously for extended duration while providing live updates via long-range 2.4GHz wireless. This architecture was adapted for the 2010 RAMboat and has been improved upon for the 2011 competition. Considerable modifications were made in 2011 by students on the team. These improvements include new batteries for motor power and the electronics required to manage the Lithium-Poly technology, new motors with more rigid attachment, a new vision computer which has added laser ranging and thermal sensing subsystems. These modifications have made the vehicle lighter and more sophisticated. Students divided into working groups for Hardware, Electronics, Computing, Navigation and Vision. The results of the latest developments are summarized both below in this paper and in more detailed presentations on the team website (oce.uri.edu/~auv/asv). Figure 1 provides an overall block diagram of ASV subsystems.

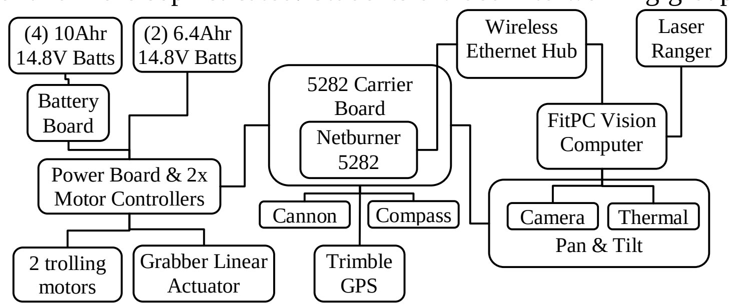


Figure 3 ASV Subsystems Block Diagram

2 Mechanical Subsystem

The structure of the ASV is based upon a *Hobie Float Cat 60* fishing platform. The Hobie hulls, connected with 1.25" aluminum tubing, provide a very stable platform for the ASV's hardware and can support a payload in excess of 250lbs. Hobie polyethylene hulls are renowned for their durability and provide a nearly unsinkable platform for the ASV. Two additional 1.25" aluminum tubes form the backbone of the ASV. Not only do these tubes provide easy mounting for hardware and payload but they also provide easy trim adjustment forward and aft. Mounted directly behind the hulls are twin trolling motors mounted directly to the aluminum backbone of the ASV.

2.1 Propulsion:

In order to provide maneuverability and power, dual Sevylor 18lb thrust trolling motors were used. The motor controller that is used in the ASV is an IBC V2 Dual Speed Controller from RobotMarketplace.com. The motor controller is mounted in the electronics box. The controller takes RC signals or a signal from the mission computer and converts it to high-current pulse width modulation (PWM) that is capable of driving high amperage brushed motors. The motor controller must have power in order to receive signals from the RC receiver or the mission computer because the RC receiver. This controller features two 50 amp heat sinked MOSFET channels that control forward and reverse functions and mix the channels for turning. The controller has an auxiliary input that is capable of controlling two weapons system relays with one RC switch or two IO lines from the mission computer. This system is used in competition for the water cannon and for tennis ball retrieval.

Using fixed thrusters for the ASV competition has advantages over the standard propeller and rudder system found on most boats. A thruster system reduces the amount of moving parts needed for steering. They also allow for turning at low speed. A rudder requires that water be moving across its face in order to turn. For the precision tasks often required in robotics, a thruster configuration provides many more advantageous than having a rudder. In addition, the trolling motors allow for the exclusion of a typical drive shaft which can be a source of leaks. The pre-attached cables on the thrusters allow them to be connected to the electronics housing through water tight fittings.

2.2 Electronics Housing:

A large watertight box is mounted aft of the centerline on the deck in order to prevent water from getting to RAMboat electronics while providing considerable space for electronics. The box is approximately 16" long, 12" wide, and7 ½" tall. A large piece of aluminum was mounted to the back of the housing as a heat sink for the FitPC. This box uses an o-ring seal and locking latches to keep all of the electronics dry. The box is made of medium weight plastic and has a clear plastic lid. Inside the box a flat piece of Lexan is mounted to the bottom to hold the battery packs and act as a platform for various standoffs and mounts for the equipment inside. The simplicity of a single box is favored as it allows easy access to all of the electronic and computer components of the vehicle, while still providing a secure and durable platform.

Inside the box a multi-tiered set up was created to secure all of the parts inside. On the bottom of the back of the box a lightweight plastic mount was created to hold the batteries. The holder constrains the several heavy batteries to be secured inside of the box. A group of connectors are attached to the batteries in order permit rapid replacement. On the side of the batteries the power management board is mounted next to the mission computer. Also mounted in the box are the power management board, the high performance Trimble GPS system, the Netburner 5282 mission computer with custom URI interface board, and the FitPC vision computer with attached disk drive.

3 Electrical Subsystems

There are two power management boards on the 2011 URI ASV. The first is the power board developed by the 2009 URI Team for the subsystem power distribution. The second is a newly developed battery board designed to tie together 4 Lithium-Poly Batteries for motor power. This new development saved the 2011 ASV roughly 10 lbs of gross vehicle weight by replacing the lead acid batteries used last year.

3.1 Power Management board

The heart of the electrical subsystems is the power management board designed to maintain and convert battery power to other voltages for subsystem distribution, while allowing for separate arrays of parallel batteries connected for the system, motor bank 1, and motor bank 2. In the case of the 2011 ASV, the power management board manages system power alone. The motor power is managed by the Battery Board discussed in the next section. The system power is fused and available through several connectors for system and subsystem power and is provided by two 6.4 Ahr, 14.8V Lithium-Poly Batteries wired to the board in parallel.

The Power Board also has the ability to transfer servo control of the motor control to signals originating from the mission CPU or from radio control under remote radio command. Additionally, it monitors voltage and current for the three isolated power systems (system and two separate motor controller supplies). All of this is available for measurement through one connector that also has room for CPU inputs for control of power conversion components on the power board. The board passes the motor control signals to a two channel mixing motor controller that is powered by the Motor Battery Board. It also lets a radio control receiver take over motor control from the computers if commanded. Below additional aspects of the Power Board’s functionality are listed:

- Connects up to 4 separate 14.8V batteries in parallel for System Power. The power board provides diode isolation, fuses and direct charge connections
- Connects up to 2 separate 12-24V batteries in parallel for each motor controller. The power board provides diode protection and fuses (AUV Implementation)
- System power is converted to 12V and 5Vfor distribution to other subsystems. Connectors for each of these converted voltages and also the system power itself are available for subsystems
- Motor controllers are mountable via standoffs over the power board. Additional fused motor controller power connecters are available from the power board (AUV Implementation)
- Motor controller input signals available from the power board, to switch control between CPU and radio
- Charging connectors and charging switches to trigger relays and disconnect motors
- Mechanical & magnetic switches for turning motors, system, and charging on and off (AUV Implementation)
- Slide switches & computer control for turning power converters on and off
- Slide switch to enable radio control
- Radio switch to enable, disable radio control
- Jumpers to connect motor power systems
- Jumper to switch radio switch output from radio control to remote motor turn off
- LEDs indicators on all battery banks to detect fuse failures

3.2 Motor Battery Board

Four 14.8V, 10Ahr Lithium-Poly batteries and a battery board were newly added to the 2011 ASV electronics subsystems for motor power. The battery board was designed and built to manage the four separate 14.8 V batteries with two available configurations, four batteries in parallel or two parallel banks of two batteries wired in series. Each battery is connected into the board and regulated with 10A fuses. The fuses are a secondary measure to keep the batteries from providing more than 10A as the batteries themselves are current limited at 10A. LED indicators were installed after each fuse to demonstrate that battery power is available on each of the 4 inputs. The batteries are paired and isolated through 30V, 30A Schottky Diodes with large heat sinks to expel the heat generated from the diode voltage drop at high amperage. The negative side of the batteries is grounded by a MOSFET that is powered by a switched latching relay which allows that the battery power be turned on and off.

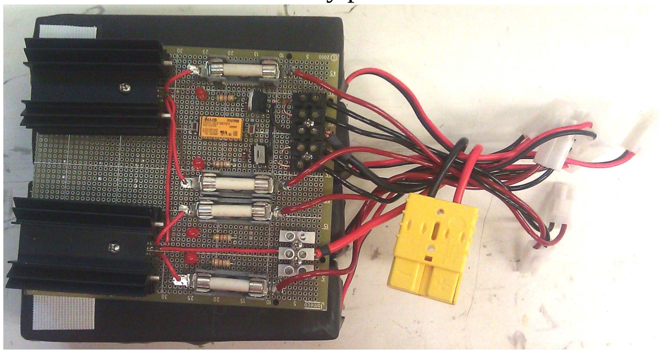


Figure 4 Power management Board (Right) and the Motor Battery Board (Left)

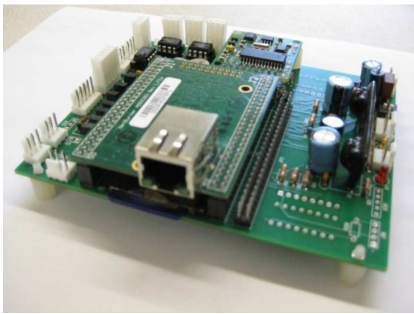
4 Computer Subsystems

Historically and for the 2011 (RoboBoat and RoboSub) AUVSI competitions, both the mission computer and the vision computer subsystems were developed to run the control code for URI's autonomous undersea and surface vehicles. The 2011 mission subsystem has strongly leveraged the architecture that has been developed over a number of years by the URI Autonomous Vehicle Team. For the 2011 competitions, the vision subsystem architecture has been redeveloped and coded onto a new FitPC Linux platform entirely in C++.

4.1 Mission Computer:

The mission subsystem, which acts as the engine room brain for the vehicles, has two parts: a custom development/carrier board and a Netburner 5282 module which sits on top. Developed by the URI team early in 2009 with sponsorship from Sunstone using their PCB123 software suite, the custom development board has power and communication input lines as well as various output lines to talk to networked computers or peripherals. The board has input ports, power lines, serial, TTL, and Ethernet communications lines, and pin connectors for GPIO. The board has optically isolated servo output signals which isolates the 5V reference voltage onboard the carrier board for A2D measurements and communications.

Sitting on top of the custom mission computer board, is the Netburner 5282 module. The NetBurner 5282 module features a web-based control interface, a full 32-bit architecture providing 60+ MIPS and the full suite of UDP and TCP/IP protocols. This 32-bit high performance processing platform provides the horsepower to handle both 10/100 Ethernet connections and resource-demanding applications while adding 8 A/D channels, pulse width generation, and pulse width measurement to standard IO. Basically, the 5282 module is used as the robots core processor, where it contains the Freescale ColdFire 5282 microprocessor, 512KBytes of Flash memory, 8MBytes of SDRAM and 10/100 Ethernet (including the magnetics, led's and RJ- 45 connector). One hundred of the processor signal pins are brought out on two 0.1" center 50-pin connectors. These signals include the address bus, data bus, chip selects, interrupt inputs, timers, QSPI, I2C, PWM, CAN 2.0, 3 UARTs, GPIO and 8 10-bit A/D inputs. Data sheets for the NetBurner 5282 can be found online at www.netburner.com.



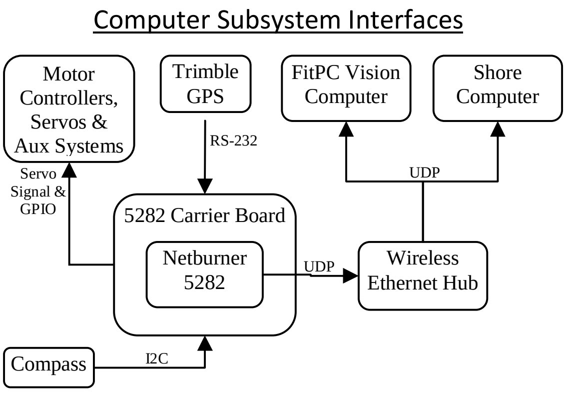


Figure 5 Netburner 5282 Mission Computer (Left) and the Computer Subsystem Block Diagram (Right)

4.2 Navigation Subsystem:

A tilt compensating compass is connected to the mission computer through I2C communications. This compass provided tilt compensated heading to within 0.1 degrees. A Trimble GPS unit is connected to the Mission computer to aid the navigation of the Autonomous Surface Vehicle. The Trimble GPS receiver uses WAAS and Omnistar position corrections to achieve sub-meter accuracy. The GPS unit is connected to the Mission computer via a RS-232 serial port connection, where it streams GPS data to the computer five times a second to aid in course following. The mission computer code was programmed to run a task (*ProcessNMEATask*) with a priority of slightly less importance than *UserMain*. When the NetBurner code begins, it initializes the GPS Com Port (*COM 1*) and then the code reads the incoming RMC and GGA NEMA strings on the mission computer and makes the information available to necessary tasks via UDP communication and logs it to a text file on its onboard SD Card.

Figure 6 Trimble BDS960 GPS

4.3 Vision Computer

The new vision computer is a FitPC2i with an Intel Atom low power CPU running at 2.0 GHz with 2 GBytes of memory, running an Ubuntu Linux OS. Vision image processing is coded in C++ using the OpenCV libraries and controls the functions and capabilities of the vision system. Because the mission tasks vary with each mission leg and UDP communications occur multiple times a second from the mission computer, the system architecture on the vision computer required multithreading capabilities alongside the vision processing algorithms. The vision system structure is comprised of a number of processing threads with more critical system processes occurring independent. The Vision control code was separated into three levels. Level One is the UDP communications control program, which communicates via UDP with the rest of the system. This thread is started as soon as the vision system starts it receives and parses status messages from the mission computer. The status message indicates which mission leg the vehicle is on and the control program then loads the appropriate Level Two code which controls the behavior specific to that leg.

The control program or core vision system processes will load a new second level code each time a new leg is started. This is necessary because of the various tasks specific for each level, such as obstacle avoidance or firing the water cannon. Depending on the necessary behavior for the specific leg and the required assistance from the vision system, a number of variables are available to the second level code which is obtained from image processing. For example, the second level may use the horizontal coordinate of a green buoy combined with a scanning laser to modify the heading based upon its location within the field of view. The status message is then modified and sent back to the mission computer. The final third layer acts as logger by storing all data recorded by the sensors and camera for the running duration, this is key for future mission planning and trouble shooting. The vision computer can be accessed wirelessly via remote desktop or command line window to launch or modify the code. A wireless hub connects the two computers and allows wireless communication and programming.

Figure 7 FitPC2i (www.fit-pc.com)

5 Vision Subsystem

5.1 Open Computer Vision

To accommodate the vision system, a variety of computer vision and image processing algorithms needed to be implemented. In the past, the vision system was implemented in MATLAB. However, this year it was decided to implement the vision system in C++ to improve performance. An excellent tool for image processing in C++ is the Open Computer Vision (OpenCV) library. OpenCV is an open source library that provides a variety of image processing and computer vision functionalities. The OpenCV library acts as the core foundation for the image processing system, and allows native access to the camera and basic image processing functionality. Due to the multithreaded nature of the vision system (Figure 8), logging images and video does not create any CPU cycle overhead allowing the system to process nearly 12 frames a second. There are a number of tasks or missions to accomplish in the competition where most of these tasks involve the identification of some object with a distinct feature or color. With this information in hand, each task adopted a two step approach; first a specific color that we were looking for was isolated. Then the image was searched for a specific shape or object size.

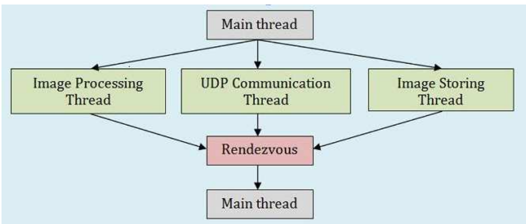


Figure 8 Vision System Structure Diagram

5.2 Color Segmentation

In order to isolate a color in an image, the RGB image must be converted to a different color space less affected by light. The HSV (Hue, Saturation, and Value) space is a common space for color image processing of this type. The resultant converted image can then be simply thresholded over the three dimensions to extract the desired color and color range. The color segmentation technique allows very quick identification of specific color ranges in an image. The resultant information from the color segmentation process is fed into the next process which identifies the size and shape of the object.

5.3 Image Recognition

The shape recognition allows task specific shapes to be identified and logged allowing very quick versatile identification classification and tracking. An example of the buoy identification and tracking mission can be seen in Figure 9**.** With the color segmentation and shape recognition as another layer to the vision system specific mission could be built on top of the systems already in place. Most of the missions require similar requirements of the vision system, one particular mission requiring more specialized mission planning is the hanging targets. The hanging targets require a number of integrated functionality running in parallel. First the hanging targets need to be identified in an image then the symbol needs to be extracted and understood, with finally the temperature extracted from each symbol. The mission requires a number of layers of complexity with from the architecture of the system is greatly reduced.

Figure 9 Buoy Recognition (Left and Middle) and Shape and Symbol Recognition (Right)

5.4 Camera

Figure 10 Logitech camera

The camera chosen for the competition is a Logitech Orbit, which has auto-focus capabilities and uses the RGB color space for data output. The Logitech Orbit is capable of 8 mega-pixel resolution for still images and 2 mega-pixel resolutions for video output. The camera resolution is scaled down to 640x480 pixels to enhance processing speed and reduce computational power requirements. The resolution of the camera controls the amount of video frames per second that can be processed. Since pixels are processed in a matrix form, the more pixels, the longer processing time required for each frame.

The camera and accompanied thermal sensor are mounted on a pan and tilt unit that allows a pan of 180 degrees and tilt of 90 degrees. This feature is utilized by C++ coding in OpenCV to command the mission computer through UDP communications to control the movement of the camera for certain tasks.
Such tasks include object tracking, object following, and search patterns that allow the camera to search for necessary objects when none are located within the field of view. The image outputs are sent through universal serial bus 2.0 to the vision computer.

6 Auxiliary systems:

6.1 Water Cannon

An on demand 12V Flojet RV water pump is used to drive the water cannon discharge under mission computer control. A simple Transistor/Mosfet control circuit allows the computer to switch the cannon on and off with a single 3.3V control line. The discharge tube is attached at the front camera pan/tilt platform so that the cannon will follow camera aiming.

6.2 Tennis Ball Capture

A linear actuator is mounted to the side of the RAMboat which actuates an extendable arm that is designed to extend to the expected distance of the tennis ball on the platform. This actuator is controlled by a motor controller that is commanded by the mission computer to extend, retract or hold position. The position of the actuator is indicated by a potentiometer in the unit which is wired back to the mission computer for A2D measurement. At the end of the arm, a capturing mechanism is restrained and it is released by a solenoid when the mission computer is commanded by the vision subsystem. Both the firing the solenoid and the arm extension control are commanded by the vision subsystem through UDP commands to the mission computer.

6.3 Laser Ranging

Figure 11 LIDAR Unit

Included in the vision system architecture is the use of a scanning laser (LIDAR) to get range and bearing to a target. The LIDAR unit is connected to the USB port of the FitPC and the range and bearing information is obtained using C++ coding in OpenCV. This laser combined with the camera allows for the creation of a powerful image processing system that resolve objects in 3D. Using the processes defined in the vision subsystem section (5) a colored target is identified and tracked and its position in the world is calculated using the range and bearing from the laser. Objects located in the world are given locations on a local tangent plane Cartesian coordinate system aligned east, north up with the +y-axis pointed true north. The x and y coordinates of the objects are resolved by converting the vehicle position to x and y coordinates and using the range and bearing from the vision subsystem to determine the position of the object. This is advantageous for mission planning as it provides information about the in-situ location of each identified target which can be fed back for improvements.

6.4 Thermal Sensing

A Phidgets 1045 IR Temperature Sensor is integrated into the camera housing and utilized by the vision subsystem. The unit utilizes an Infra Red thermometer in order to make non contact temperature measurements. The sensor is factory calibrated and has a 10 degree field of view. The object temperature range is -70 to 380°C. The sensor connects directly to the USB port of the Vision subsystem FitPC and the temperature information is extracted using C++ coding in OpenCV.

Figure 12 Phidgets Thermal Sensor

7 Advisors

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Capt. Fred Pease, Boat captain and machinist

8 Sponsors

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COEUT/URI Center of Excellence
Battelle
Trimble / Pacific Crest
DaneTech
URI College of Engineering
Raytheon
The Mathworks
Ocean Server

9 Testing Photos

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